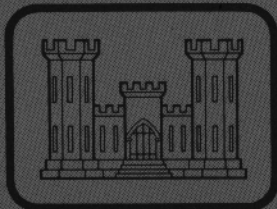
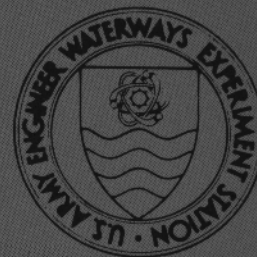


SYNTHESIS OF RESEARCH RESULTS



DREDGED MATERIAL RESEARCH PROGRAM



TECHNICAL REPORT DS-78-19

AN INTRODUCTION TO HABITAT DEVELOPMENT ON DREDGED MATERIAL

December 1978
Final Report

Approved For Public Release; Distribution Unlimited

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

THE DMRP SYNTHESIS REPORT SERIES

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20. ABSTRACT (Continued).

Procedures for considering and selecting the habitat development alternative involve a preliminary assessment of potential followed by a detailed evaluation of feasibility. Factors considered include characterization of the dredged material, site selection, engineering, cost of alternatives, sociopolitical implication, and environmental impact. Specific procedural guidelines are presented for marsh, upland, and island development.

Marsh establishment has received more attention than any other habitat development alternative, and techniques have been developed to enable careful planning, design, and propagation of these habitats. Terrestrial habitat development is primarily the application of established wildlife management and soil reclamation procedures at a particular disposal area. The feasibility of both the marsh and terrestrial habitat development alternatives has been documented in numerous field and laboratory studies. Island habitat development uses a standard technique to dispose of dredged material and create exceptionally important wildlife habitat. This is often a viable alternative that can be greatly improved by management techniques. The development of aquatic habitats, such as seagrass meadows and oyster flats, on dredged material appears to offer significant potential for the creation of highly productive biological communities and at the same time provide for large disposal quantities; however, aquatic habitat development is largely untested in the field.

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PREFACE

This report presents an overview of the dredged material disposal alternatives involving habitat development. The report was prepared as part of the Corps of Engineers' Dredged Material Research Program (DMRP) under the Habitat Development Project (HDP). The DMRP was conducted by the Environmental Laboratory (EL) of the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., for the Office, Chief of Engineers.

This report was prepared by Dr. Hanley K. Smith, Manager of the HDP, under the general supervision of Dr. John Harrison, Chief, EL, and Dr. Roger T. Saucier, Special Assistant for Dredged Material Research. Careful review was provided by the following members of EL: Dr. Robert J. Diaz, Ms. L. Jean Hunt, Dr. R. Terry Huffman, Ms. Mary C. Landin, Mr. John D. Lunz, Dr. Robert F. Soots, and Ms. Mary K. Vincent.

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COL John L. Cannon, CE, was Commander and Director of WES during the preparation of this report. Mr. Fred R. Brown was Technical Director.

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AN INTRODUCTION TO HABITAT
DEVELOPMENT ON DREDGED MATERIAL

PART I: INTRODUCTION

1. Habitat development refers to the establishment of relatively permanent and biologically productive plant and animal habitats. The use of dredged material as a substrate for habitat development offers a disposal technique that is, in many situations, a feasible alternative to more conventional open-water, wetland, or upland disposal options. The purpose of this report is to summarize the various habitat development alternatives, discuss their applicability, and establish a routine for habitat selection.

2. Four general habitats are suitable for establishment on dredged material: marsh, upland, island, and aquatic. Within any habitat several distinct biological communities may occur. For example, the development of a dredged material island may involve a wide variety of habitats (Figure 1). For the purposes of this report, these habitat types are defined as follows.

- a. Marsh: A wetland dominated by nonwoody vegetation. Most commonly these will be tidal freshwater and saltwater marshes and relatively permanently inundated freshwater marshes.
- b. Upland: A very broad category of terrestrial communities characterized by vegetation that is not normally subject to inundation. Types may range from bare ground to mature forest.
- c. Island: An upland habitat distinguished by isolation and completely surrounded by water or wetlands.
- d. Aquatic: Typically submerged habitats extending from near sea level down to several metres. Examples are tidal flats, oyster beds, seagrass meadows, and clam flats.

3. A general habitat selection procedure is outlined in Part II, while succeeding parts deal with more specific aspects of each alternative. Techniques for actual construction and development of a specific habitat are not discussed. For habitat development methodologies, the

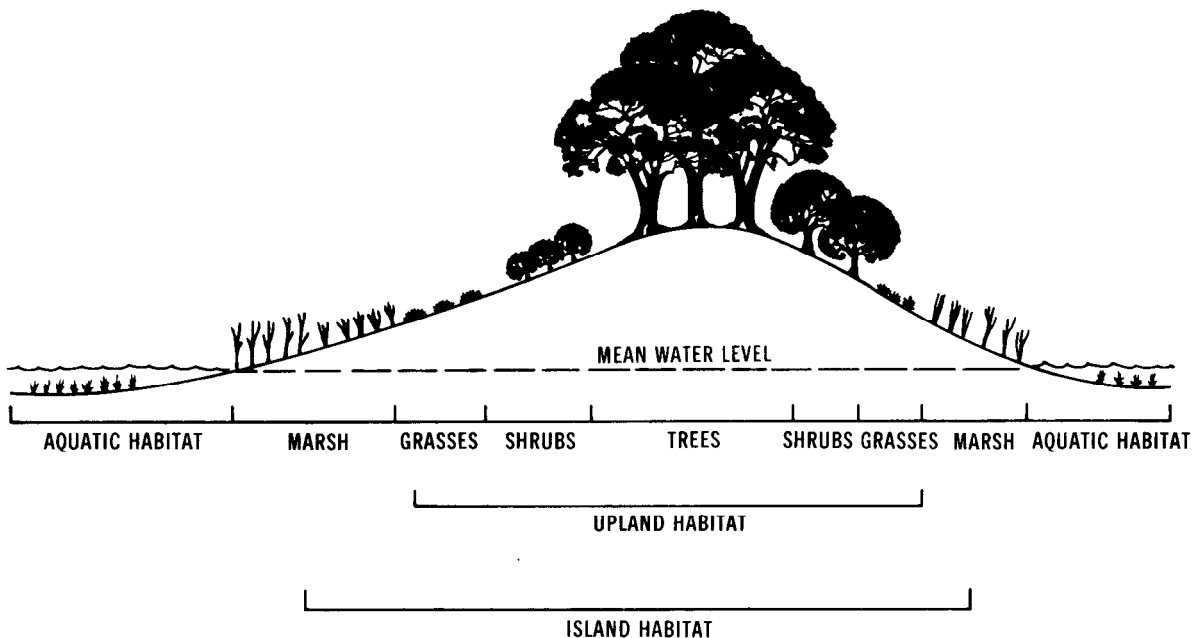


Figure 1. Hypothetical site illustrating the diversity of habitat types that may be developed at a disposal site

reader is directed to the U. S. Army Engineer Waterways Experiment Station (WES) Dredged Material Research Program (DMRP) synthesis reports entitled: "Wetland Habitat Development with Dredged Material: Engineering and Plant Propagation," "Upland Habitat Development with Dredged Material: Engineering and Plant Propagation," "Development and Management of Avian Habitat on Dredged Material Islands," and "Upland and Wetland Habitat Development with Dredged Material: Ecological Considerations." A listing of appropriate reference documents for each habitat type is included in the Selected Bibliography.

PART II: SELECTION

5. The diversity of biological communities indicates the potential diversity of alternatives available under habitat development. This wide range of options will usually make using quantitative measures for selecting specific alternatives impractical, and, consequently, selecting a given habitat development alternative is likely to be highly judgmental. The best determination will be made by a combination of local biological and engineering expertise and public opinion. No specific criteria are offered here for selection among habitat development alternatives; however, guidelines for the evaluation of individual situations are presented.

Conditions Favoring Habitat Development

6. The selection of habitat development as a disposal alternative will be competitive with other disposal options when one or more of the following conditions exist:

- a. Public/agency opinion strongly opposes other alternatives.
- b. Recognized habitat needs exist.
- c. Enhancement measures on existing disposal sites are identified.
- d. Feasibility has been demonstrated locally.
- e. Stability of dredged material deposits is desired.
- f. Habitat development is economically feasible.

7. Disposal alternatives are often severely limited and constrained by public opinion and/or agency regulations. Constraints on open-water disposal and disposal on wetlands or the availability of upland disposal sites may leave habitat development as the most attractive alternative. In many cases, habitat development will have strong public appeal.

8. In many situations, the need for restoration or mitigation or the need for additional habitat may strongly influence the selection of

the habitat development alternative. This is particularly applicable in areas where similar habitat of considerable value or public concern has been lost through natural processes or construction activities.

9. Habitat development may be used as an enhancement measure to improve the acceptance of a disposal technique. For example, seagrass may be planted on submerged dredged material, or wildlife food plants established on upland confined disposal sites. Habitat development has considerable potential as a low-cost mitigation procedure and may be used to offset environmental impacts incurred in disposal.

10. The concept of habitat development is more apt to be viewed as a feasible alternative if it has been successfully demonstrated locally. Even the existence of a pilot-scale project in a given locale will offset the uncertainties often present in the public perception of an experimental or unproven technique.

11. The vegetation cover provided by most habitat alternatives will often stabilize dredged material and prevent its return to the waterway. In many instances this aspect will reduce the amount of future maintenance dredging necessary at a given site and result in a positive environmental and economic impact.

12. The economic feasibility of habitat development should be considered in the context of long-term benefits. Biologically productive habitats have varied but unquestionable value (e.g., sport and commercial fisheries) and are relatively permanent features. Consequently, habitat development may be considered a disposal option with long-term economic benefits that can be applied against additional costs that may be incurred in its implementation. Most other disposal options lack this benefit.

13. Habitat development may be particularly economically competitive in situations where it is possible to take advantage of natural conditions or where minor modifications to existing methods would produce desirable biological communities. For example, the existence of a low energy, shallow-water site adjacent to an area to be dredged may provide an ideal marsh development site and require almost no expenditure beyond that associated with open-water disposal.

Procedural Guidelines

14. Habitat development presents several options ranging from establishment of upland communities to the development of seagrass meadows. A broad procedural guide to the selection of the habitat development alternative is given in Figure 2. Text discussions are keyed to Figure 2 and subsequent figures by use of italics for terms that appear in those figures. The user should ignore categories unrelated to his particular problem, and may wish to add key site specifications.

Preliminary assessment

15. The initial consideration of habitat development as a disposal alternative should include a *preliminary assessment* of feasibility, which involves judgment based on available data. A determination that habitat development is not initially feasible should be based on compelling negative evidence and not merely lack of information or specific precedents. In the absence of such negative evidence, proceed to the *detailed evaluation of feasibility*. Factors may arise at several stages in the evaluation that would lead to a determination of infeasibility. Should that occur, other disposal alternatives would be reconsidered.

Detailed evaluation

16. The *detailed evaluation of feasibility* includes six major categories beginning with a *characterization of the dredged material* and arranged generally in the order of need for acquisition of information. In characterizing the dredged material, the physical and *engineering characteristics* of the material to be dredged should be determined. These properties will help define the general considerations of *site selection*.

17. *Site selection* should be based on an adequate knowledge of *energy conditions, foundation characteristics, salinity, tidal influences, and bottom topography*. Energy conditions will largely influence the feasibility of establishing a stable substrate, or the necessity of protective structures. Foundation characteristics will determine the ability of a given site to support construction activities or structures.

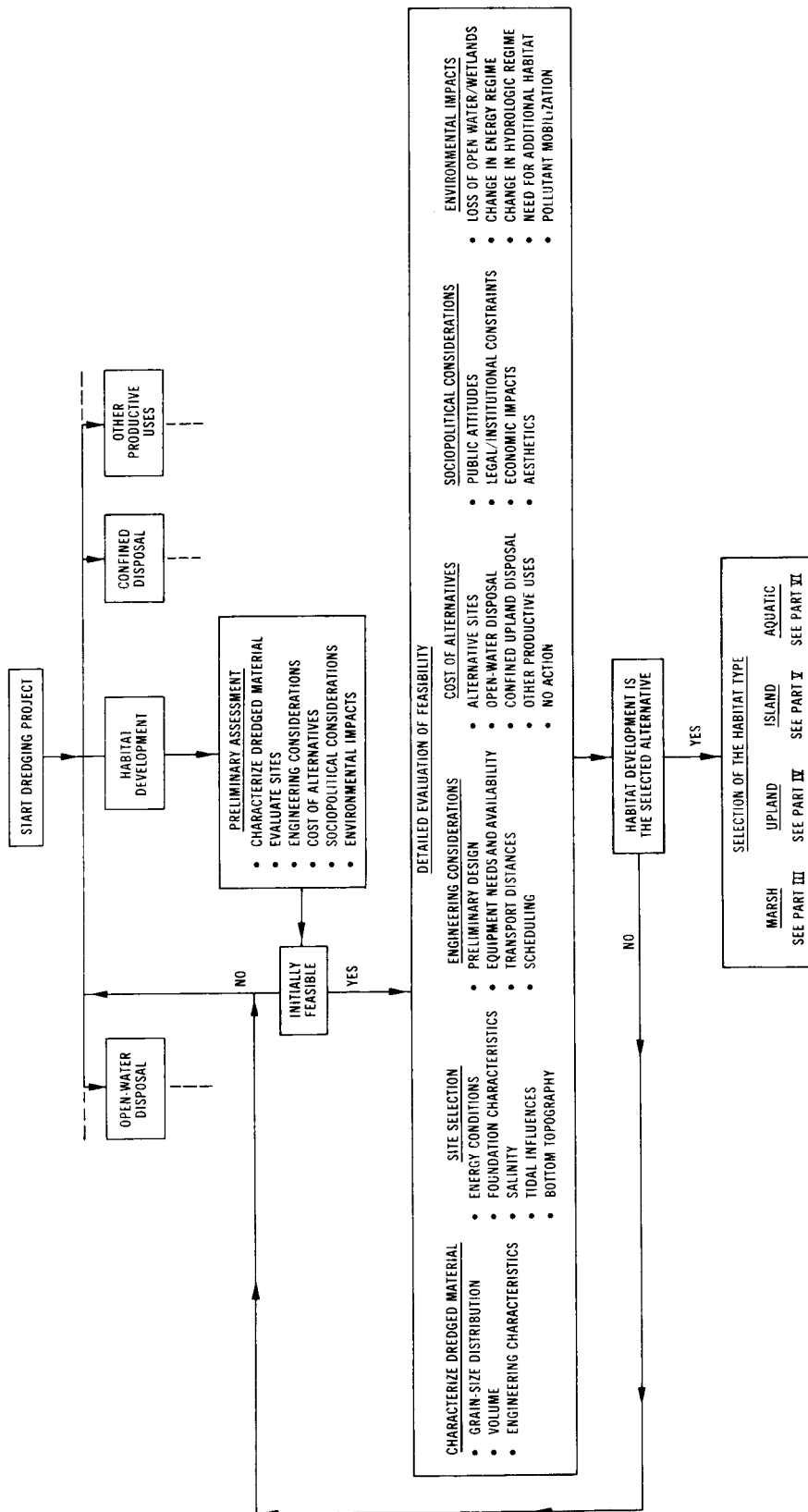


Figure 2. Procedural guidelines for selection of habitat development alternatives

Salinity and tidal influences will dictate the plant species composition. A more detailed analysis of these factors will be necessary later for detailed design purposes if the habitat development alternative is selected, but even in this early phase, some field sampling may be necessary if general information is not available.

18. *Engineering considerations* at this stage are largely confined to *preliminary designs* and an assessment of *equipment needs and availability*. Details such as *scheduling* to meet critical environmental dates (e.g., spring or summer planting times) and the identification of dredged material *transport distances* will provide useful planning data. In many projects, the pivotal determination of either engineering feasibility or infeasibility can be made at this stage.

19. Evaluation of the *cost of alternative* disposal methods is the next essential step. Detailed economic analyses must await the further development of design criteria; however, a general cost comparison of the various *alternative sites* should be possible at the completion of the detailed evaluation of feasibility. This is another critical step because considerable time and effort can be spared by defining the economic limits that the project must satisfy to remain competitive with other alternatives.

20. Of the *sociopolitical considerations*, *public attitudes* and *legal and institutional constraints* are most likely to prove limiting. Negative public attitudes generally occur when the community views the proposed habitat as a threat to established values. Legal and institutional constraints frequently arise when there are unanswered questions of ownership and access or when local developmental interests have designated the site for an alternative future use. Direct *economic impacts* may be identified if the habitat to be developed may alter important shellfishing or recreational areas or block a water view.

21. The *environmental impact* of most habitat development projects may be expressed as a *loss of open-water habitat or wetland systems* and *changes in hydraulic and energy regimes*. The impacts of these factors tend to be cumulative and are directly related to the perceived *need for additional habitat*. In general, the need for more habitat is

considered more critical in areas that have lost or are losing considerable habitat of that type. *Pollutant mobilization* by plants growing on contaminated dredged material might be of concern and its potential should be determined prior to habitat development.

Selection of alternative

22. Upon completion of the *detailed evaluation of feasibility*, a determination can be made as to whether habitat development is applicable. If *habitat development is the selected alternative*, a decision regarding the type or types of habitats to be developed must be made. As indicated earlier, this decision will be largely judgmental, but in general, site peculiarities will not present more than one or two logical options. In the following parts, each of the habitat alternatives is discussed in general terms. Specific advantages and disadvantages likely to be encountered are evaluated and items of particular concern during early feasibility determinations are highlighted.

PART III: MARSH DEVELOPMENT

23. Marshes are considered any community of grasses or herbs that experiences periodic or permanent inundation. Typically these are intertidal freshwater or saltwater marshes and relatively permanently inundated freshwater marshes. Marshes are recognized as often extremely valuable natural systems and are accorded importance in food and detrital production, fish and wildlife cover, nutrient cycling, erosion control, floodwater retention, groundwater recharge, and esthetics. Marsh values are highly site specific and must be interpreted in terms of such variables as species composition, location, and extent, which in turn influence their impact upon a given ecosystem.

Considerations

24. Marsh creation is the best understood of the habitat development alternatives, and accurate techniques have been developed to estimate costs and to design, construct, and maintain these systems. Methods are available to predict the impact of the alternatives on the environment and to describe the value of the proposed resource prior to its selection.

Advantages

25. The following advantages are most frequently identified with marsh development:

- a. Considerable public appeal.
- b. Creation of desirable biological communities.
- c. Considerable potential for enhancement or mitigation.
- d. Frequently a low cost option.

26. Marsh development is a disposal alternative that can generate strong public appeal and has the potential of gaining wide acceptance when other techniques cannot. The habitat created has biological values that are readily identified and are accepted by many in the academic, governmental, and private sectors. However, application requires an

understanding of local needs and perceptions and the effective limits of the value of these ecosystems.

27. The potential of this alternative to replace or improve marsh habitats lost through dredged material disposal or other activities is frequently overlooked. Marsh development techniques are sufficiently advanced to design and construct productive systems with a high degree of confidence. Additionally, these habitats can often be developed with very little increase in cost above normal project operation, a fact attested to by hundreds of marshes that have been inadvertently established on dredged material.

Disadvantages

28. The following problems are most likely to be encountered in the implementation of this alternative:

- a. Unavailability of appropriate sites.
- b. Loss of other habitats.
- c. Release of contaminants.
- d. Loss of site for subsequent disposal.

29. By far the most difficult aspect of the application of marsh development is the location of suitable sites. Low energy, shallow-water sites are most attractive; however, cost factors will become significant if long transport distances are necessary to reach low energy sites. Protective structures may be required if low energy sites cannot be located.

30. Marsh development frequently means the replacement of one desirable habitat with another, and this will likely be the source of most opposition to this alternative. There are few reliable methods for comparing the various losses and gains associated with this habitat conversion; consequently, determining the relative impact may best be made on the basis of the professional opinion of local authorities.

31. The potential for plants to take up and then release contaminants into the ecosystem through consumption by animals or decomposition of plant material should be recognized when contaminated sediments are used for habitat development. Although this process has not been verified in the laboratory or field as a serious problem, the possibility

must be considered. Effective and conventional techniques are available to determine this probability of uptake.

32. Development of a marsh at a given site can prevent the subsequent use of that area as a disposal site. In many instances, any future development on that site would be prevented by State and Federal regulations. Exceptions may occur in areas of severe erosion or where the initial disposal created a low marsh and subsequent disposal would create a higher marsh.

Procedural Guidelines

Marsh development

33. The procedural guidelines established in Part II for habitat development are directly applicable to marsh development. It is suggested that during the *detailed evaluation of feasibility* (Figure 2) particular emphasis be placed on *site selection* and the *need for additional marsh habitat*. Site selection is discussed in detail below. The perceived need for additional marsh will generally be a local judgmental decision and may be pivotal in public and other agency acceptance of this concept. It will be most readily accepted in those areas where marsh is rapidly eroding or where large areas of marsh have been destroyed. In situations where shallows and marshes are in equilibrium or where open water is limited, marsh development may be viewed as having a neutral or negative impact.

Selection of wetland type

34. If *marsh development is the selected alternative*, it is necessary to *select the wetland type* (Figure 3). In most situations, the selection of a wetland type will be largely predetermined by overriding environmental conditions such as tidal range and salinity. Most marsh development projects, simply because of the nature of dredged material disposal and the formation of drainage patterns, will contain elements of shallow and deep marsh (fresh water) or high and low marsh (saltwater).

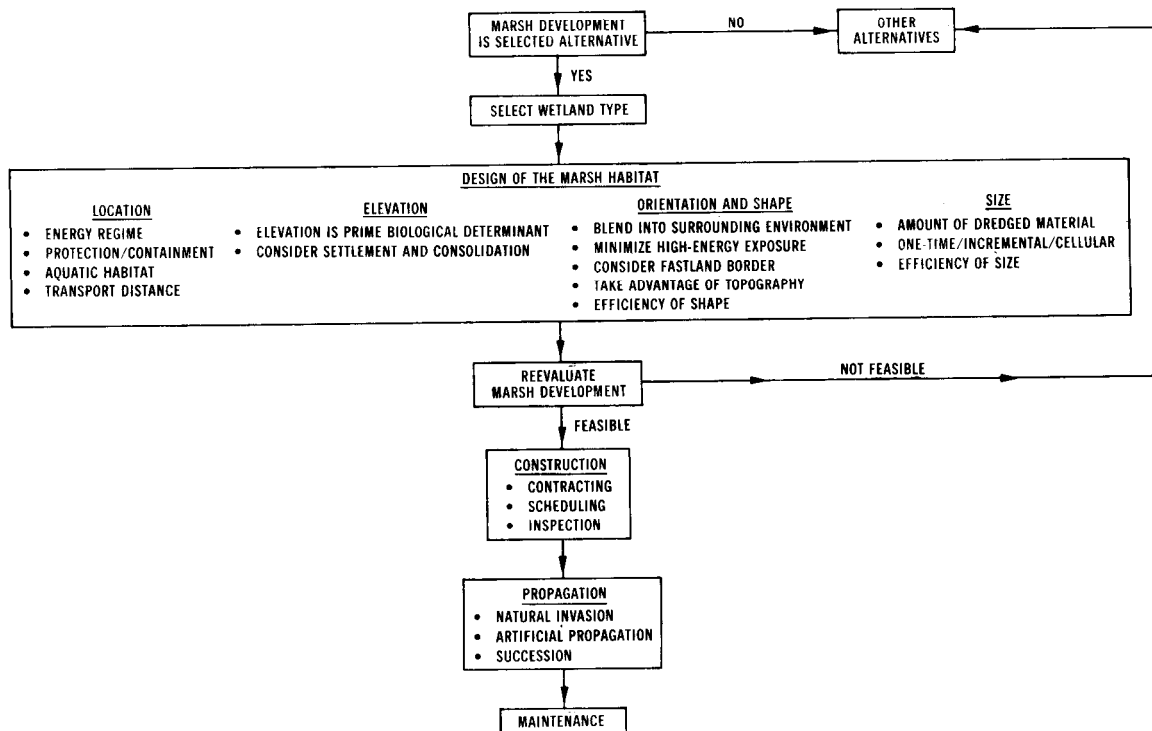


Figure 3. Procedural guidelines for selection of marsh habitat development

Design of marsh habitat

35. The detailed *design of the marsh habitat* is separated into four parts: *location*, *elevation*, *orientation and shape*, and *size*. The design should maintain the goals of disposal of dredged material through the development of a desirable biological community, using the most cost-efficient method and causing a minimum of environmental perturbation.

36. The *location* of the new marsh may be the most important decision in marsh development. Low *energy* areas are best suited for

marsh development, and sandy dredged material is the ideal substrate.* Departure from these conditions will require a careful evaluation of the need for structural *protection and containment*. High hydraulic energies (wave, current) may prevent the formation of a stable substrate and the establishment of vegetation, and, therefore, various forms of protective structures or mechanisms would be required. Correspondingly, less protection is required under conditions of lower hydraulic energy.

37. Another major consideration in the protection/containment equation is the grain-size distribution of the dredged material. If one of the project objectives is to hold the material within a prescribed area, hydraulically placed, fine-grained material will generally require containment. Containment usually becomes progressively less critical as coarser grained material is placed.

38. Site energy and dredged material grain-size distribution are closely interrelated in determining the need for protection and containment. Hydraulically placed clay will usually require containment, regardless of wave or current conditions. Silt under very low energy situations may require no containment or protection. Sand that would require no protection under low energy situations may require some protection under moderate wave energy. Obviously a wide range of conditions exists.

39. Careful consideration should be given to the value of the *aquatic habitat* at the disposal site. Those areas best suited for marsh development (shallow, low energy) are also likely to be biologically productive. Particular efforts should be made to avoid unusually productive areas such as seagrass meadows, clam flats, and oyster beds.

* Low energy areas are most frequently found in the lee of beaches, islands, and shoals; in shallow water where wave energies are dissipated; on the convex side of river bends (point bars); in embayments where marshes presently exist; and away from long fetch exposure, tidal channels, inlets, and headlands. Significant amounts of sand are often available during dredging even in projects that involve primarily fine-grained material. In some situations, it will be possible to stockpile and then use this sand as a protective top dressing on finer substrates or to use the sand to construct a protective dike or breakwater if needed.

40. A final, major consideration in marsh siting is *transport distance*. In general, the farther material must be moved, the greater the cost. The availability of suitable equipment may also influence the feasibility of distant disposal. Therefore, attention should be given to location of the disposal site near the dredging operation.

41. Final *elevation* of the marsh substrate is largely determined by *settlement and consolidation* and is the most critical of the operational considerations as it dictates both the amount of material disposed and the biological productivity of the habitat established. Techniques are available to predict the final stable elevation of a given volume of dredged material placed in a confined intertidal situation. Salt marshes are generally most productive within the upper third of the tidal range, while freshwater marshes should generally be flooded to a depth of between 0.1 and 1.0 m. Determination of final elevation is critical and should be based on precise knowledge of the elevational requirements of the plant community. Variation in topography will produce habitat diversity and should be encouraged, provided that the majority of the area is within the desired elevation range. If the possibility of not being able to achieve a desired elevation appears likely, two courses of action are apparent. First, if incremental filling is possible, a conservative estimate of the amount of material necessary to attain a given elevation is in order. Should the final elevation be too low, then the difference can be made up in subsequent disposal. If one-time disposal is anticipated, it may be possible to overfill and rework the area to a lower elevation at a later date.

42. The *orientation and shape* of the new marsh will largely determine its total cost, its efficiency as a disposal site, and its effectiveness as a biological addition to the natural environment. The shape should minimize impact on drainage or current patterns in the existing environs and, insofar as possible, present a scene that appears natural enough to *blend into the surrounding environment*. If high energy forces are anticipated, the marsh should be shaped to *minimize high energy exposure*. Such design will reduce the threat of failure

and reduce the cost involved in providing protection. If available, a *fastland border*, such as a cove, island, or breakwater, can serve as low cost protection and minimize the length of otherwise necessary and costly containing or protective structures. An effort should be made to *take advantage of bottom topography* during the design of the new marsh. Disposal sites are often not uniform in depth; if possible, protective structures should be located in shallow water and the fill area in deep water to maximize the containment efficiency. If dikes are built from local material, it may be possible to deepen the disposal area by locating borrow material within the dike area.

43. *Shape* may be a major cost determinant when diking is required. For a given area of protected marsh, a circle requires the minimum dike length. A rectangle increases dike length in proportion to its length-width ratio. For example, a rectangle ten times longer than wide requires a perimeter nearly twice that of a circle to contain the same area.

44. The *size* of the disposal area will be a function of the *in situ amount of the material* to be dredged and the volume of the disposal area. There are several filling options that might affect size, including *one-time*, *incremental*, and *cellular*. One-time filling implies that a site will be filled and marsh established within a discrete operation and that the area will not be used again for disposal. In incremental filling it is recognized that the site will be used during the course of more than one dredging operation or season and the disposal area will be considered full when a predetermined marsh elevation is attained. In cellular filling, a compartment of a prescribed disposal area is filled to the desired elevation during each disposal project. Both incremental and cellular filling offer the efficiency of establishing a large disposal site and utilizing it over a period of years, thus avoiding repetitive construction, design, and testing operations. A major difference between these two methods is that the cellular method provides a marsh substrate at the end of each season, whereas many years may be required before incremental filling attains this goal. Both cellular and incremental filling benefit from an

efficiency of size. That is, for most disposal area configurations, an increase in the length of the dike provides proportionally more disposal area. Cellular or incremental disposal sites would generally be larger than one-time disposal sites, and this increase in size may offer a more cost-effective disposal site.

Reevaluation and construction

45. *Reevaluation of the marsh development alternative* is in order subsequent to the detailed design. *Construction* will follow if the reevaluation is favorable. *Contracting* procedures in marsh development may prove difficult because, in most instances, the contractors will have no previous experience with this type of disposal operation. Pre-bid conferences to explain the intricacies of the project as well as carefully detailed contract specifications are strongly advised. *Scheduling* the dredging can prove to be particularly important. In order to obtain maximum vegetative cover within the first year, it is necessary to have the dredged material in place and with a relatively stable surface elevation by the beginning of the growing season. Delays will affect the initial success of the project and may result in loss of nursery or seed stock, replanting costs, adverse public reaction, and unwanted erosion at the site. Careful *inspection* of the disposal operation is essential as the attainment of the prescribed elevation is critical, an aspect that may not be appreciated by the dredging crew.

Propagation

46. *Propagation* of marsh plants can be attained by *natural invasion* or *artificial propagation*. Natural establishment of plants can be expected if the environmental requirements for a marsh community, including a source of propagules, are present at a site. In some cases, natural invasion will occur on a site within a few months, in others many years may be required. The process of marsh establishment may be accelerated in many instances by seeding or sprigging.* The advantage

* In the selection of species for artificial propagation, every effort should be made to ensure that the selected species represent a natural assemblage for a given area. Exotic or offsite species will not generally be able to compete with natural invaders. An exception may be an instance in which a species is selected for temporary cover or erosion control until natural invasion has colonized the site.

of propagation by natural invasion is the low cost, and this may be a pivotal consideration in borderline projects. The advantages in sprigging are more rapid surface stabilization and an immediate vegetation cover.

Maintenance

47. Dredged material marshes should be designed to be relatively *maintenance* free. The degree of maintenance will largely depend on the energy conditions at the site, a factor that should be included in the cost analysis of the project. No maintenance may be required to protect the new marsh in low energy situations. In areas of somewhat higher energy conditions, protection may be required only until the marsh has a chance to mature. In those areas, protective structures may be designed for a relatively short life with no additional maintenance required. In high energy situations, perpetuation of the marsh may require planned periodic maintenance of protective structures.

PART IV: UPLAND HABITAT DEVELOPMENT

48. Upland habitats encompass a variety of terrestrial communities ranging from bare soil to dense forest. In the broadest interpretation, upland habitat occurs on all but the most disturbed disposal sites. For example, a gravelly and bare disposal site may provide nest sites for killdeer; weedy growth may provide cover for raccoons or a food source for seed-eating birds; and water collected in desiccation cracks may provide breeding habitat for mosquitoes. The essential fact is that man-made habitats will develop regardless of their management; however, the application of sound management techniques will greatly improve the quality of those habitats.

Considerations

49. Upland habitat development has potential at hundreds of disposal sites throughout the United States. Its implementation is largely a matter of the application of well-established agricultural and wildlife management techniques.

Advantages

50. Upland habitat development as a disposal option has several distinct advantages:

- a. Adaptability.
- b. Improved public acceptance.
- c. Creation of biologically desirable habitats.
- d. Elimination of problem areas.
- e. Low-cost enhancement or mitigation.
- f. Compatibility with subsequent disposal.

51. Upland habitat development, more than any of the other habitat development alternatives, may be used as an enhancement or mitigative measure at new or existing disposal sites. The principles and applications of this technique are adaptable to virtually any upland disposal situation. Regardless of the condition or location of a disposal area, considerable potential exists to convert it into a more productive

habitat. Small sites in densely populated areas may be keyed to small animals adapted to urban life, such as seed-eating birds and squirrels. Larger tracts may be managed for a variety of wildlife including waterfowl, game mammals, and rare or endangered species.

52. The knowledge that a site will ultimately be developed into a useful area, be it a residential area, a park, or wildlife habitat, improves public acceptance. Many idle and undeveloped disposal areas that are now sources of local irritation or neglect would directly benefit from upland development, and such development may well result in more ready acceptance of future disposal projects.

53. In general, upland habitat development will add little to the cost of disposal operations. Standard procedures may involve liming, fertilizing, seeding, and mowing. A typical level of effort would be similar to that applied for erosion control at most construction sites and considerably less than that encountered in levee maintenance.

54. Upland habitat development, unless the target habitat is forest, will generally be compatible with subsequent disposal operations. In most situations, a desirable vegetative cover can be produced in one growing season. Subsequent disposal would simply require recovery of the lost habitat. Indeed, the maintenance of a particular vegetation stage may require periodic disposal to retard or set back succession.*

Disadvantages

55. The disadvantages of upland habitat development are potential opposition to subsequent disposal and possible necessity of long-term management.

56. The primary disadvantage of this alternative is related to public acceptance. The development of a biologically productive area at a given site may discourage subsequent disposal or modification of land use at that site. This problem could be avoided by the clear

* Vegetation succession is the orderly process of community change in which one plant community replaces another. In typical upland succession: bare ground→grassland→shrubs→forest. For many types of wildlife management, the earlier stages of succession are most productive.

identification of future plans prior to habitat development, or by the establishment and maintenance of biological communities recognized as being most productive in the earlier stages of succession. In the latter case, subsequent disposal may be a necessary management tool.

57. Some habitat type will require management. For example, if annual plants are selected for establishment (corn and barley are prime wildlife foods), then yearly planting may be necessary. If the intent is to maintain a grassland or open-field habitat, it may be necessary to mow the area every 2 to 5 years to retard woody vegetation. In most cases, it will be possible to establish very low maintenance habitats, but if the intent is to establish and perpetuate a given habitat type, long-term management may be essential and expensive.

Procedural Guidelines

Upland habitat development

58. Several factors introduced in the general procedural guidelines found in Part II (Figure 2) merit particular consideration prior to the detailed planning of the dredging operation if upland habitat development is a selected disposal alternative. Those habitats in limited supply should be identified and the *need for additional habitat* assessed. *Public attitudes* are of particular consequence in the implementation of this alternative, and public opinion should be actively sought.

59. *Site selection* should be made with a particular target habitat in mind as the importance of other habitats will be greatly influenced by the needs and attributes of the surrounding area. The chemical and physical properties and the relative quantities of different types of dredged material should be evaluated to determine the characteristics of the soil to be used in the habitat development. Several remedial treatments are possible. For example, it may be possible to improve the agricultural characteristics of the surface layer by top dressing the site with material selected for its agronomic characteristics. Alternatively, it may be possible to bury a problem soil.

Planning and design

60. Assuming that *upland habitat development* has been selected as a disposal alternative or as an enhancement measure, the next step is *habitat planning and design* (Figure 4).

61. The criteria discussed under *site considerations* are applicable regardless of whether the site is a new or previously used disposal area. *Local needs* and thereby *target species* will be determined primarily by the desires of the State wildlife agencies and those of the public. These needs are likely to reflect local perception of the value of wildlife. If the area has a strong hunting tradition, the emphasis may be on game animals. If there is strong agency concern for an endangered species, that may be the emphasis. In many cases, a target species per se will not be identified. Rather a grouping such as "song-birds" or "small game" will be designated.

62. The list of target species must be evaluated in light of the *available habitat* surrounding the site and the *size* of the disposal site. The size of a disposal area will seldom be large enough to exert a significant impact on regional animal populations if it only duplicates existing habitat types. Therefore, the success of the site will usually be determined by its ability to complement surrounding habitats or remedy *limiting factors*.*

63. The basic *management* decisions will depend on the *type* of disposal and *future plans* at the site. If one-time disposal with periodic maintenance is planned, the management plan may be quite flexible.

* The concept of limiting factors is central to the practice of wildlife management. Essentially it states that the necessity of life (food, cover, space, etc.) that approaches a critical minimum will tend to limit the population. For example, if water is a necessity to a target population and if water is not available, management that does not increase the availability of water will not increase the target population. Habitat development on dredged material frequently offers the potential of treating limiting factors. For example, island habitat development for nesting colonial birds is promising because it provides isolated breeding habitat that is otherwise in short supply (a limiting factor). The value of the created habitat will be greatly enhanced if it can meet a need not presently fulfilled (i.e., satisfy a limiting factor).

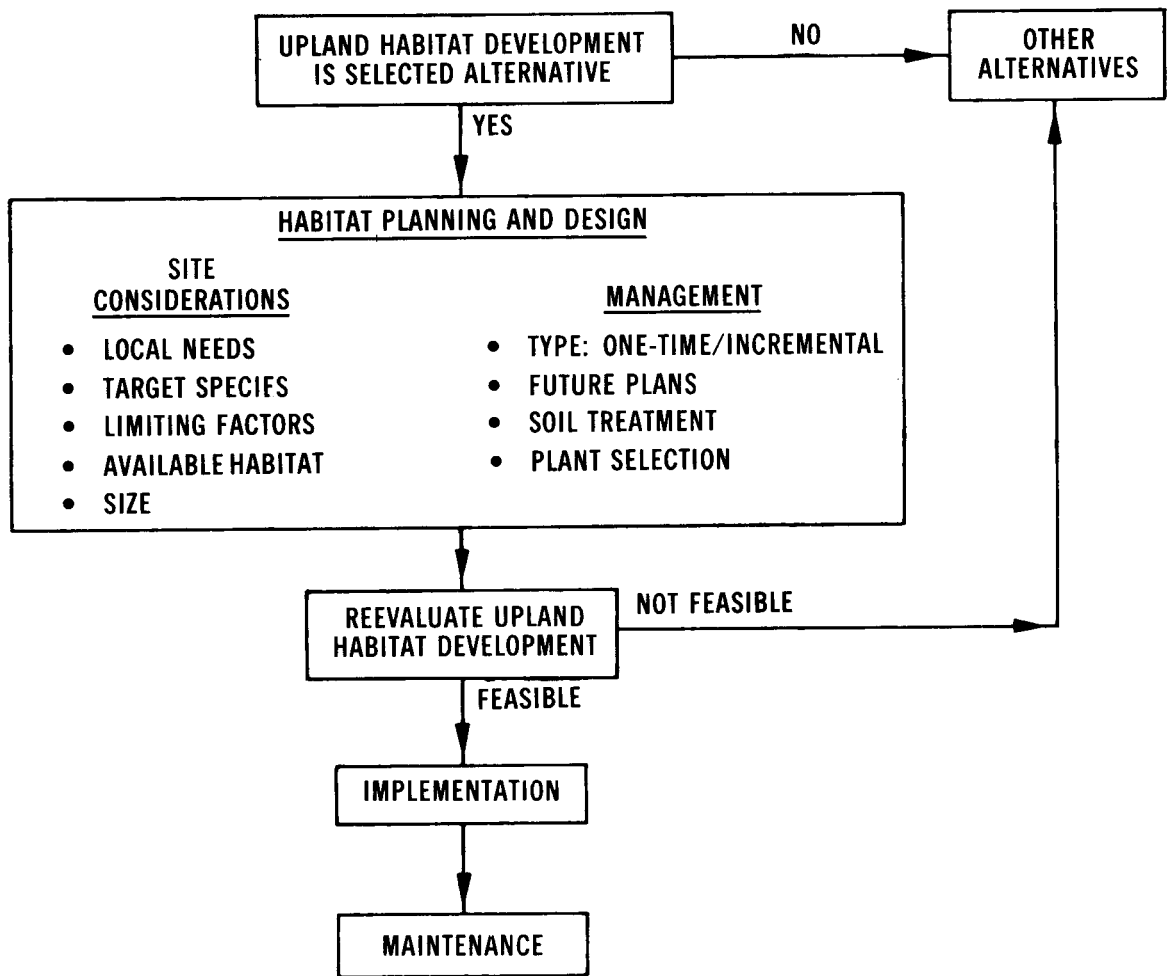


Figure 4. Procedural guidelines for selection of upland habitat development

One-time disposal without management indicates the need to establish a plant community that is relatively self sustaining. If periodic disposal is planned, plant communities that are rapidly functional are advised. Properly planned, periodic disposal could be considered a wildlife management option used to control succession or diversify the habitat and avoid confrontation regarding subsequent activities. *Future plans* for any habitat development site should be well documented and understood by interested agencies and the public prior to implementation.

64. *Soil treatment and plant selection* are closely related and can proceed after determination of the type of disposal, identification of the characteristics of the dredged material, and determination of target species have been completed. Soil treatment may include a variety of activities such as burying problem materials, dewatering, mixing materials to obtain improved soil characteristics, leaching, fertilization, and liming. Plant selection will be dictated by soil conditions and habitat preferences.

65. In many situations it will be possible to identify highly desirable natural plant communities near the disposal area. Development of site conditions (soil, elevation, diversity) on dredged material that are similar to those of desirable plant communities will encourage natural invasion and natural development of similar communities. When this is possible, a considerable savings in planting and maintenance costs may be realized.

Reevaluation and implementation

66. If, upon *reevaluation*, the upland habitat development alternative remains feasible, the project may be *implemented* and subsequently maintained. *Implementation* will be highly site specific but should present few difficulties beyond the problems typically encountered in contracting new or unusual work. Advice from local wildlife biologists and soil scientists may prove invaluable in this stage.

Maintenance

67. The various ramifications of *management* have been discussed in paragraphs 63-65. Designation of the organization responsible for

this *maintenance* may prove far more difficult than the activity itself, thus emphasizing the need for the design of low maintenance habitats. In the case of long-term disposal operations, the Corps or local sponsor may be the designated manager. Private organizations or State wildlife agencies may assume this responsibility on disposal sites with high potential (many disposal sites have become Audubon Society Bird Sanctuaries).

PART V: ISLAND HABITAT DEVELOPMENT

68. Dredged material islands range in size from a few square feet to several hundred acres. Island habitats are here considered terrestrial communities, completely surrounded by water or wetlands and distinguished by their isolation and limited food and cover. Because they are isolated and relatively predator free, they have particular value as nesting and roosting sites for numerous species of sea and wading birds (gulls, terns, egrets, herons, and pelicans). The importance of dredged material islands to nesting species frequently decreases as the size and age increases because larger and older islands are more likely to support predators. However, isolation is more important than size, and thus large isolated islands may be very attractive to nesting birds.

69. Dredged material islands are found in low to medium energy sites throughout the United States. Typically these islands are located next to navigation channels and are characteristic of the Intracoastal Waterway. They are generally composed of sandy and shelly dredged material. In recent years, most active dredged material islands have been diked to improve the containment characteristics of the sites.

Considerations

70. The importance of dredged material islands as nesting habitats for sea and wading birds cannot be overemphasized. In some states (North Carolina and Texas, for example), a majority of the nesting of these colonial species occurs on man-made islands.

Advantages

71. Island habitat development has the following advantages:

- a. Employment of a traditional disposal technique.
- b. Use of existing disposal areas.
- c. Provision of critical nesting habitats.
- d. Management conducive to subsequent disposal.

72. Island habitat development utilizes a traditional disposal technique: the confined or unconfined disposal of dredged material in marsh or shallow water or on existing islands. Consequently, few unconventional operational problems should occur in its implementation.

73. In many coastal areas, the careful selection of island locales and placement will encourage use by colonial nesting birds. Properly applied, island habitat development is an important wildlife management tool: it can replace habitats lost to other resource priorities, provide new habitats where nesting and roosting sites are limiting factors, or rejuvenate existing disposal islands.

74. Planned disposal on existing dredged material islands is often conducive to their management for wildlife. Nesting is almost always keyed to a specific vegetation successional stage, and periodic disposal may be used to retard or set back succession to a more desirable stage. As a practical matter, disposal on existing islands has largely replaced new island development because of opposition to the loss of open-water and bottom habitats. Consequently, habitat development on dredged material islands will frequently be keyed to the disposal on and management of existing islands.

Disadvantages

75. Island habitat development has the following disadvantages:

- a. Interruption of hydrologic processes.
- b. Destruction of open-water or marsh habitats.
- c. Need for careful placement of material and selection of the disposal season.

76. Alteration of the water energy regime by the placement of barriers such as islands deserves particular attention in terms of the potential for changing temperature, salinity, and circulation patterns and sedimentation dynamics of the affected body of water. Large-scale projects or projects in particularly sensitive areas may warrant the development of physical, chemical, and biological models of the aquatic system prior to project implementation.

77. Dredged material islands, by the nature of their location, may reduce the presence of wetlands and/or open water and associated

benthic habitats. This impact may be minimized by careful site selection or disposal on existing sites. Containment of the material behind dikes will lessen the lateral spread of material, but may adversely affect the value of the island to birds.

78. Disposal on any dredged material island should be immediately preceded by a visit to determine if the site is an active nesting colony. The use of dredged material islands by birds may occur with or without management. When colonies are present, scheduling of subsequent disposal operations and placement of material should be planned to minimize disruption of the disposal operations as well as the colonies involved. Destruction of the nests of many colonial seabirds is a criminal offense punishable by fine and/or imprisonment.

Procedural Guidelines

Island development

79. The general procedural guidelines found in Part II (Figure 2) should be modified by the following guidelines specific to island habitat. The initial consideration should include an assessment of the likelihood that island habitat development will indeed attract a target population. Although colonial nesting bird use of dredged material islands is very common in many areas of the United States, it is uncommon in some areas. Colonial nesting is highly visible and if it occurs within a given area, it is usually common knowledge among natural resource agencies and local amateur bird watchers. (Note that local authorities may not realize that a nesting site is a dredged material island.)

Design

80. If, after the detailed evaluation of feasibility, island development is selected, the *design* of the island habitat should include three major considerations: *location, shape and orientation, and size* (Figure 5).

81. The *energy regime* of the island site should be of particular concern. Success will be most easily obtained in relatively shallow,

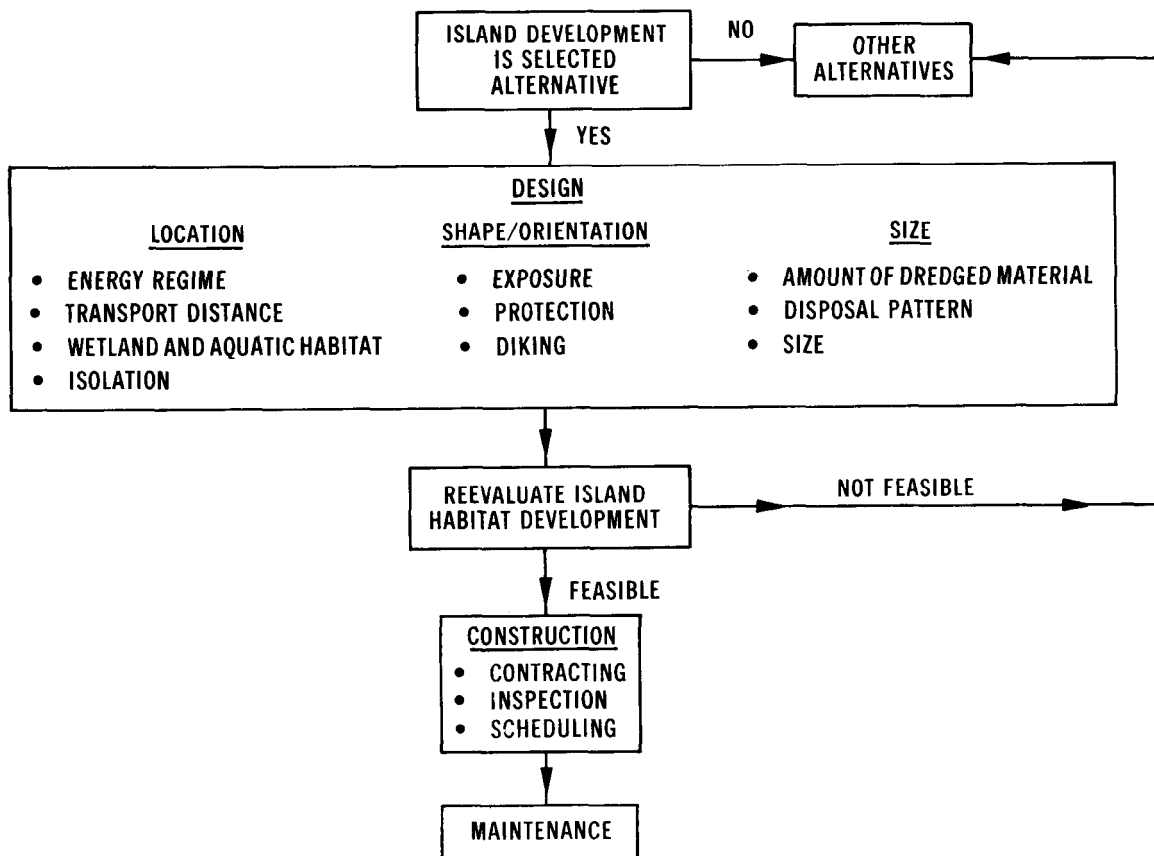


Figure 5. Procedural guidelines for selection of island habitat development

low energy areas. Promising sites include active areas of deposition such as the lee of beaches, islands, and shoals and the convex side of river bends. Islands subjected to even moderate wave forces will tend to erode and migrate toward the lee and may eventually disappear. The cost of increased *transport distance* to reach a low energy area may, however, require a compromise on location. Islands may be located in moderate energy sites if permanence is not required or if structural stabilization procedures are employed. (For example, the windward side may be riprapped.)

82. The placement of new islands will entail a loss of *wetland or aquatic habitat* and involves a trade-off. Many intangibles confound the trade-off decision. While it is desirable to avoid biologically productive areas, these same areas are likely to be the quiet shallow waters ideal for island siting. If the island is used for nesting, it may be exceptionally valuable habitat; however, it will not be possible to predict use in all instances. If the island is not used by birds, it may have very little value. Frequently the decision will rest on the selection of the least disruptive alternative and nonmitigated losses simply accepted.

83. *Isolation* is important in site location. The value of these sites lies largely in the fact that they are isolated from mammalian and reptilian predators and human disruption. Since most predators will travel short distances across marshes or through water to reach a promising food source, the likelihood of disturbance decreases with the distance from a predator population. The location of islands near food sources for juvenile and adult birds is more important to some species than others although such relationships are poorly understood.

84. The *shape and orientation* of a dredged material island may greatly affect its stability. Typically, newly placed dredged material islands are elongated and oriented parallel to the dredged site. One or more mounds on the island represent the outfall of the disposal pipe. Depending upon the flexibility of the dredging equipment, islands could be shaped to minimize exposure to erosive forces or to avoid biologically sensitive areas. Structural protection such as riprap may be

required in the absence of a suitable energy condition. Again the island should be oriented in such a way that the area of maximum exposure is minimized.

85. Existing dredged material islands are often *diked* using material borrowed from the site prior to additional disposal. The purpose of the dike is to prevent the spread of new material onto adjacent aquatic systems. If possible, this technique should be avoided on islands selected for habitat development because it usually reduces the value of the habitat to nesting birds. Decision criteria in this case would match the potential value of a site to target nesting species and the local importance of the benthic community.

86. The *size* of the dredged material island will reflect the *amount of dredged material* and the *pattern of disposal*. The larger an island, the greater its potential for supporting a predator population. The maximum desirable size of an island will be influenced by many factors, but generally islands should not exceed 8 to 10 ha. The most desirable *disposal pattern* is a series of small, separate islands.

Reevaluation and construction

87. If, upon *reevaluation*, island habitat development is selected, the project may proceed to the construction stage. *Construction* of dredged material islands will seldom involve unconventional techniques or methodologies. However, modifications to standard procedure, such as the precise placement of material, may be overlooked by dredging crews, and both the *contractor* and the *inspector* should be alerted to the purpose and importance of these modifications. *Scheduling* is of particular significance in the placement of new materials on existing islands as care must be taken to avoid disposal on active colonies.

Maintenance

88. The *maintenance* of dredged material islands offers significant opportunity to both dispose of dredged material and to provide important habitat. In those areas where nesting is common, a management plan should be developed to identify desirable disposal sites and to avoid disruption of colonies. The use of an island by birds usually does not mean that that site should not be used as a disposal site. Indeed,

survival of the colony may require retardation of plant succession or addition of material to replace that lost by erosion. Scheduling of disposal should be such that colonies are not disturbed but may involve little more than inspection of a site before disposal or avoidance of existing islands during the nesting season.

PART VI: AQUATIC HABITAT DEVELOPMENT

89. Aquatic habitat development refers to the establishment of biological communities on dredged material at or below mean tide. Potential developments include such communities as tidal flats, sea-grass meadows, oyster beds, and clam flats. The thesis for this promising but largely untested alternative is that the bottom of many water bodies could be altered using dredged material, and in many cases this would simultaneously improve the characteristics of the site for selected species and permit the disposal of significant quantities of material.

Considerations

90. With the exception of many unintentional occurrences and a few intentional small-scale demonstration projects, this alternative is untested. Because of its largely theoretical nature, the discussion here will be limited to key points likely to be encountered or considered at any site.

Advantages

91. The following advantages to aquatic habitat development are recognized:

- a. High biological production.
- b. Potential for wide application.
- c. Complements other habitats.

92. Aquatic habitats may be highly productive biological units. Seagrass beds are recognized as exceptionally valuable habitat features providing both food and cover for many fish and shellfish. Oyster beds and clam flats have high recreational and commercial importance. Dredged material disposal projects impacting aquatic communities predictably incur strong criticism, and in these instances reestablishment of similar communities may be feasible as a mitigation or enhancement technique. In many instances it will be possible to establish aquatic habitats as part of marsh habitat development.

93. This concept potentially has very wide application as most dredging projects are flanked by open water. In many instances, the selective subaquatic placement of material will both enhance the disposal site and accommodate large amounts of dredged material.

Disadvantages

94. The primary and overriding feature of aquatic habitat development is an inadequate understanding of techniques for applying this alternative. Prudent application at this time will involve careful site-by-site determination combined with local biological and engineering expertise.

Procedural Guidelines

95. The lack of specific guidance should not eliminate the consideration of this alternative. Adequate technical judgment will considerably reduce the risk factor. Because of the diversity of communities available in this alternative, no specific guidelines have been presented; however, most aspects of habitat development presented in the preliminary assessment and the detailed evaluation of feasibility (Figure 2) will be applicable to aquatic habitat development. Of particular significance will be hydraulic energies along the bottom. The interaction of the texture of the material with the hydraulic energies of the site will be significant as the material must provide a stable surface substrate. The possibility that alteration of the bottom configuration of a waterway could adversely affect current patterns should be carefully considered. In large projects or in those projects where some question exists regarding the impact, it may be advisable to develop physical, chemical, and biological models of the aquatic system prior to project implementation.

SELECTED BIBLIOGRAPHY OF DREDGED MATERIAL RESEARCH PROGRAM REPORTS
PERTINENT TO HABITAT DEVELOPMENT

	HABITAT ENGINEERING	ENVIRONMENTAL IMPACTS	MARSH DEVELOPMENT	UPLAND HABITAT DEVELOPMENT	ISLAND DEVELOPMENT	AQUATIC HABITAT DEVELOPMENT
<u>EFFECTS OF DREDGING AND DISPOSAL ON WATER QUALITY (TASK 1C)</u>						
*Transformations of heavy metals and plant nutrients in dredged sediments as affected by oxidation reduction potential and pH (1C05, CR D-77-4) (NTIS Nos. AD A041 468 and AD A041 469).		✓				
Water quality impacts of aquatic dredged material disposal (laboratory investigations) (1C07, TR DS-78-4).		✓	✓		✓	✓
<u>EFFECTS OF DREDGING AND DISPOSAL ON AQUATIC ORGANISMS (TASK 1D)</u>						
Vertical migration of benthos in simulated dredged material overburdens (1D03, TR D-78-35).		✓	✓			✓
The availability of sediment-adsorbed heavy metals to benthos with particular emphasis on deposit-feeding infauna (1D06, TR D-78-42).		✓	✓			✓
Effects of suspended dredged material on aquatic animals (1D09, TR D-78-29) (NTIS No. AD A058 489).		✓	✓			✓
An evaluation of oil and grease contamination associated with dredged material containment areas (1D11, TR D-77-25) (NTIS No. AD A048 595).		✓	✓			✓
Effects of dredging and disposal on aquatic organisms (1D13, TR DS-78-5).		✓	✓	✓	✓	✓
<u>POLLUTION STATUS OF DREDGED MATERIAL (TASK 1E)</u>						
*Selective partitioning of sediments to evaluate potential mobility of chemicals during dredging and disposal operations (1E04, TR D-76-7) (NTIS No. ADA 035 247).		✓	✓	✓	✓	✓
Long-term release of contaminants from dredged material (1E07, TR D-78-49).		✓	✓	✓	✓	✓
<u>EFFECTS OF MARSH AND TERRESTRIAL DISPOSAL (TASK 2A)</u>						
Mineral cycling in salt marsh-estuarine ecosystems (2A05, TR D-78-3) (NTIS No. AD A052 737).		✓	✓			
The effects of smothering a <i>Spartina alterniflora</i> salt marsh with dredged material (2A07, TR D-78-38).		✓	✓			
Upland and wetland habitat development with dredged material: ecological considerations (2A08, TR DS-78-15).		✓	✓	✓	✓	✓
<u>CONTAINMENT AREA OPERATIONS (TASK 2C)</u>						
Feasibility of the functional use of vegetation to filter, dewater, and remove contaminants from dredged material (2C02, TR D-76-4) (NTIS No. AD A028 336).		✓	✓			
Design and construction of retaining dikes for containment of dredged material (2C04, TR D-77-9) (NTIS No. AD A045 311).	✓		✓	✓		
*Identification of objectionable environmental conditions and issues associated with confined disposal areas (2C06, CR D-74-4) (NTIS No. AD A000 895).		✓	✓	✓	✓	
Assessment of low-ground-pressure equipment for use in containment area operation and maintenance (2C09, TR DS-78-9).	✓		✓	✓		
Abatement of malodors at confined dredged material disposal sites (2C11, CR D-76-9) (NTIS No. AD A030 597).	✓	✓	✓	✓	✓	
An investigation of physical, chemical, and/or biological control of mosquitoes in dredged material disposal areas (2C12, TR D-78-48).	✓	✓	✓	✓	✓	
Guidelines for designing, operating, and managing dredged material containment areas (2C18, TR DS-78-13).	✓		✓	✓		
Landscaping concept development for confined dredged material sites (5E01, CR D-75-5) (NTIS No. AD 026 684).	✓	✓		✓	✓	
<u>CONFINED DISPOSAL AREA EFFLUENT AND LEACHATE CONTROL (TASK 2D)</u>						
Physical and chemical characterization of dredged material influents and effluents in confined land disposal areas (2D01, TR D-78-24) (NTIS No. AD A057 460).		✓	✓	✓		
Physical and chemical characterization of dredged material sediments and leachates in confined land disposal areas (2D05, TR D-78-43) (NTIS No. AD A055 781).		✓		✓		
<u>UPLAND DISPOSAL CONCEPTS DEVELOPMENT (TASK 3B)</u>						
Dredged material transport systems for inland disposal and/or productive use concepts (3B01, TR D-78-28).	✓		✓	✓		
<u>MARSH DEVELOPMENT (TASK 4A)</u>						
*Identification of relevant criteria and survey of potential application sites for artificial habitat creation (4A01, CR D-76-2) (NTIS No. AD A033 525).	✓		✓			
*State-of-the-art survey and evaluation of marsh plant establishment techniques: induced and natural (4A03, CR D-74-9) (NTIS No. AD A012 837).			✓		✓	
*Primary productivity of minor marsh plants in Delaware, Georgia, and Maine (4A04A1, TR D-77-36) (NTIS No. AD A051 164).			✓	✓		
Underground biomass dynamics and substrate selective properties of Atlantic coastal salt marsh plants (4A04A2, TR D-77-28) (NTIS No. AD A055 761).			✓	✓		
Common marsh plant species of the Gulf Coast area. Volume I: Productivity. Volume II: Growth dynamics. (4B04B, TR D-77-44) (NTIS Nos. AD A052 094 and AD A052 095).			✓	✓		
Modeling of ecological succession and production in estuarine marshes (4A05, TR D-77-35) (NTIS No. AD A051 929).		✓	✓			
Trace and toxic metal uptake by marsh plants as affected by Eh, pH, and salinity (4A06, TR D-77-40) (NTIS No. AD A050 914).		✓	✓			

(Continued)

Note: This list was updated through January 1979.

* Report is out of print, but can be purchased from NTIS (address: National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22151). In requesting copies from NTIS, the NTIS number should be included if given. The telephone number of NTIS is Area Code 703 557-4650 (FTS access number + 557-4650).

SELECTED BIBLIOGRAPHY (CONTINUED)

	HABITAT ENGINEERING	ENVIRONMENTAL IMPACTS	MARSH DEVELOPMENT	UPLAND HABITAT DEVELOPMENT	ISLAND DEVELOPMENT	AQUATIC HABITAT DEVELOPMENT
<u>MARSH DEVELOPMENT (TASK 4A) (Continued)</u>						
Design concepts for in-water containment structures for marsh habitat development (4A07A, TR D-78-31).	✓		✓			
*Guidelines for material placement in marsh creation (4A08, CR D-75-2) (NTIS No. AD 010 725).	✓		✓			
Pregermination requirements and establishment techniques for salt marsh plants (4A09, MP D-77-1) (NTIS No. AD A045 514).			✓			
Habitat development field investigations, Windmill Point Marsh Development Site, James River, Virginia: Summary Report (4A11M, TR D-77-23).	✓	✓	✓			
Appendix C: Acute impacts on the macrobenthic community (4A11K, TR D-77-23) (NTIS No. AD A055 319).		✓	✓			
Appendix D: Environmental impacts of marsh development with dredged material: Botany, soils, aquatic biology, and wildlife (4A11I, TR D-77-23).		✓				
Appendix E: Environmental impacts of marsh development with dredged material: Metal and chlorinated hydrocarbon compounds in marsh soils and vascular plant tissues (4A11J, TR D-77-23).		✓				
Appendix F: Environmental impacts of marsh development with dredged material: Sediment and water quality (4A11DGH, TR D-77-23).		✓	✓			
Habitat development field investigations, Buttermilk Sound Marsh Development Site, Atlantic Intracoastal Waterway, Georgia: Summary Report (4A12A, TR D-78-26).	✓	✓	✓			
Appendix A: Propagation of marsh plants and postpropagation monitoring (4A12A, TR D-78-26).			✓			
Habitat development field investigations, Bolivar Peninsula Marsh and Upland Habitat Development Site, Galveston Bay, Texas: Summary Report (4A13K, TR D-78-15).	✓		✓	✓		
Appendix D: Propagation of vascular plants and postpropagation monitoring of botanical, soils, aquatic biota, and wildlife resources (4A13F, TR D-78-15).			✓			
Habitat development field investigations, Rennie Island Marsh Development Site, Grays Harbor, Washington: Summary Report (4A14D, TR D-78-11) (NTIS No. AD A056 909).	✓	✓	✓			
*Hydroponic study of heavy metal uptake by selected marsh plant species (4A15, TR D-76-5) (NTIS No. AD A033 224).		✓	✓			
Prediction of heavy metal uptake by selected marsh plants based on chemical extraction of heavy metals from dredged material (4A15A, TR D-78-6) (NTIS No. AD A054 129).		✓	✓			
Feasibility study for Dyke Marsh Demonstration Area, Potomac River, Virginia (4A17, TR D-76-6) (NTIS No. AD A033 524).	✓		✓			
Detailed design for Dyke Marsh Demonstration Area, Potomac River, Virginia (4A17A, TR D-77-13) (NTIS No. AD A048 179).	✓		✓			
Habitat development field investigations, Pond #3 Marsh Demonstration Area, San Francisco Bay, California: Summary Report (4A18A, in press).	✓	✓	✓			
Habitat development field investigations, Apalachicola Bay Marsh Development Site, Apalachicola Bay, Florida (4A19A, TR D-78-32).	✓	✓	✓			
Influence of pregermination conditions on the viability of selected marsh plants (4A21, TR D-78-51).			✓			
*Recent and planned marsh establishment work throughout the contiguous United States (4A25, CR D-77-3).	✓		✓			
Field bioassay test for detecting contaminant uptake from dredged material by marsh plants (4A26, MP D-78-6).		✓	✓			
<u>TERRESTRIAL HABITAT DEVELOPMENT (TASK 4B)</u>						
Habitat development field investigations, Nott Island Upland Habitat Development Site, Connecticut River, Connecticut: Summary Report (4B04C, TR D-78-25).	✓	✓		✓		
Habitat development field investigations, Miller Sands Marsh and Upland Habitat Development Site, Columbia River, Oregon: Summary Report (4B05M, TR D-78-38).	✓	✓	✓	✓		
*Establishment and growth of selected freshwater and coastal marsh plants in relation to the characteristics of dredged sediments (4B06, TR D-77-2) (NTIS No. AD A039 495).		✓	✓			
Handbook for terrestrial wildlife habitat development on dredged material (4B08, TR D-78-37).				✓	✓	
Upland habitat development with dredged material: Engineering and plant propagation (4B09, TR D-78-51).	✓			✓	✓	
A comprehensive study of successional patterns of plants and animals at upland disposal areas (5B03, CR D-77-2).				✓	✓	
<u>AQUATIC HABITAT DEVELOPMENT (TASK 4E)</u>						
Seagrass literature survey (4E01, TR D-78-4) (NTIS No. AD A054 480).						✓
Habitat development field investigations, Port St. Joe Seagrass Demonstration Site, Port St. Joe, Florida: Summary Report (4E02, TR D-78-33).						✓
<u>ISLAND HABITAT DEVELOPMENT (TASK 4F)</u>						
Colonial birds nesting on man-made and natural sites in the U. S. Great Lakes (4F01A, TR D-78-10).					✓	
Use of dredged material islands by colonial seabirds and wading birds in Texas (4F01B, TR D-78-8) (NTIS No. AD A056 785).					✓	
Colonial bird use and plant succession on dredged material islands in Florida (4F01C, TR D-78-14) (NTIS No. AD A056 086).					✓	
Colonial nesting sea and wading bird use of estuarine islands in the Pacific Northwest (4F01E, TR D-78-17) (NTIS No. AD A056 926).					✓	

(Continued)

SELECTED BIBLIOGRAPHY (Concluded)

An aerial survey of waterbird colonies along the Upper Mississippi River and their relationship to dredged material deposits (4F01F, TR D-78-13) (NTIS No. AD A056 059).

A comparison of plant succession and bird utilization on diked and undiked dredged material islands in North Carolina estuaries (4F02, TR D-78-9) (NTIS No. AD A056 000).

Development and management of avian habitat on dredged material islands (4F03, TR DS-78-18).

DREDGED MATERIAL DENSIFICATION (TASK 5A)

Guidelines for dewatering/densifying confined dredged material (5A21, TR DS-78-11).

DISPOSAL AREA REUSE (TASK 5C)

Classification and engineering properties of dredged material (5C02, TR D-77-18).

DISPOSAL AREA LAND USE CONCEPTS (TASK 5D)

Guidance for land improvement using dredged material (5D06, TR DS-78-21).

TREATMENT OF CONTAMINATED DREDGED MATERIAL (TASK 6B)

Treatment of contaminated dredged material (6B10, TR DS-78-14).

TURBIDITY PREDICTION AND CONTROL (TASK 6C)

Prediction and control of dredged material dispersion around dredging and open-water pipeline disposal operations (6C, TR DS-78-13).

HABITAT ENGINEERING	ENVIRONMENTAL IMPACTS	MARSH DEVELOPMENT	UPLAND HABITAT DEVELOPMENT	ISLAND DEVELOPMENT	AQUATIC HABITAT DEVELOPMENT
				✓	
				✓	
✓		✓	✓	✓	
✓	✓	✓	✓	✓	✓
✓					
✓	✓	✓	✓	✓	✓
✓	✓	✓	✓	✓	✓

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Smith, Hanley Kerfoot

An introduction to habitat development on dredged material / [by Hanley K. Smith]. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

40 p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; DS-78-19)

Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C.

Bibliography: p.38-40.

1. Dredged material. 2. Dredged material disposal. 3. Habitat development. 4. Habitats. 5. Marsh development. 6. Wildlife habitats. I. United States. Army. Corps of Engineers.

II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; DS-78-19.

TA7.W34 no.DS-78-19